CLAIMS

1. An apparatus (20) for the production of powder from a wire (31) comprising:

a recirculating gas path having: a first portion extending between a reaction chamber (100) in which an initial particulate is generated by an EEW process and an extractor (32) which extracts at least a portion of such particulate from the recirculating gas; and a second portion returning from the extractor to the reaction chamber;

a wire source (400) located external to the reaction chamber and delivering the wire along a wire path extending into the chamber, an upstream portion of the wire path isolated from the recirculating gas in the reaction chamber;

a first electrode (200) having an aperture (258) circumscribing the wire path within the reaction chamber;

a second electrode (202) proximate a terminal end of the wire path within the reaction chamber; and

an energy source (26) of electrical energy coupled to the first and second electrodes to selectively apply a discharge current between the first and second electrodes sufficient to explode a length of the wire to form said initial particulate.

2. The apparatus of claim 1 further comprising:

a turbine (600) within the recirculating gas path upstream of the reaction chamber and downstream of the extractor.

3. The apparatus of claim 1 wherein the first portion includes cooled surfaces (652, 656) for removing heat from particles moving along the first portion.

4. The apparatus of claim 1 wherein the first portion includes a cooled helicoid surface (656).

5. The apparatus of claim 1 wherein less than 1% of the initial particulate returns to the reaction chamber along the recirculating gas path.

6. The apparatus of claim 1 wherein the extractor (32) comprises a filter element (716) having upstream and downstream surfaces, the portion of the particulate normally accumulating on the upstream surface until a sufficient amount of such portion has caked on

said upstream surface to allow ejection of such caked particulate and cause such particulate to fall into a hopper (704).

7. The apparatus of claim 6 wherein said filter element (716) is a porous sintered stainless steel element having a submicron pore size.

8. The apparatus of claim 1 wherein:

the first electrode has a plurality of such apertures, the first electrode shiftable to sequentially bring each such aperture into the operational position.

9. The apparatus of claim 8 wherein:

the first electrode includes at least a portion shiftable via rotation about a first axis (249) to sequentially bring each such aperture into the operational position.

10. The apparatus of claim 9 wherein the first electrode (200) comprises:

a body (231); and

a plurality of inserts (254) mounted within the body, each insert defining an associated one of the apertures.

11. The apparatus of claim 10 wherein each insert:

is formed of a tungsten-copper sinter;

is mounted within the body from beneath; and

includes a central channel (258) having a relatively wide upstream portion (260) and a relatively narrow downstream portion (261) defining said associated aperture.

12. The apparatus of claim 11 wherein:

the first electrode includes is moveable to permit adjustment of an operative spacing between the first electrode and the second electrode.

13. The apparatus of claim 12 wherein:

the first electrode (200) includes a spider plate (230) which is vertically movable to provide said adjustment, the body being mounted for rotation about the first axis relative to the spider plate.

14. The apparatus of claim 1 wherein:

the second electrode is supported by and electrically coupled to the energy source by a conductor (203) extending through the chamber wall and within the chamber substantially surrounded by an insulator (204); and

a substantially nonconductive baffle surrounds the insulator and has a slope which is directed generally downward toward the outlet effective to guide any stubs remaining after explosion out of the chamber.

15. The apparatus of claim 14 wherein a stub trap (644) is provided between the chamber and the extractor.

16. The apparatus of claim 1 wherein the wire source comprises a spool from which the wire is drawn endwise.

17. The apparatus of claim 14 wherein the spool is nonmoving during drawing of the wire.

18. The apparatus of claim 1 wherein the wire is stepwise advanceable along the wire path.

19. The apparatus of claim 1 further comprising:

a wire straightening mechanism (402) comprising:

a first engagement member (468) receiving the wire from the wire source; and

a second engagement member (470) downstream of the first engagement member during operation the first and second engagement members being reciprocally moveable relative to each other to place an at least partially inelastic longitudinal strain on a length of the wire between the first and second engagement members of between 1% and 10% of a yield strain.

20. The apparatus of claim 19 wherein the first and second engagement members respectively comprise first and second clamps which are closeable to grasp the wire and openable to release the wire, in operation one such clamp (468) being fixed along the wire path and the other clamp (470) being moveable by an actuator between a first location in which the other clamp grasps the wire in a relatively unstrained condition and a second

location in which the other clamp releases the wire at said at least partially inelastic longitudinal strain.

21. The apparatus of claim 1 further comprising a processing subsystem (33) coupled to the extractor (32) and comprising:

a processing chamber (800) containing a processing gas;

a plurality of vessels (826) within the processing chamber each having an upper port and a lower port, the vessels moveable through a plurality of vessel positions, including:

a loading position in which the vessel receives, through its upper port, powder separated by the extractor;

at least one processing position in which the processing gas may communicate through the upper port for contacting the powder in the vessel; and

an unloading position in which the vessel discharges, through its lower port, processed powder.

22. The apparatus of claim 21 wherein the processing chamber includes a carousel (832) rotatable through a plurality of orientations to move the vessels through the plurality of vessel positions

23. The apparatus of claim 22 wherein said vessel positions include:

a liquid agent delivery position in which a the vessel receives, through its upper port, a liquid agent which coats and/or chemically reacts with the powder separated by the extractor.

24. The apparatus of claim 23 wherein said vessel positions include:

a mixing position in which a mixing element is inserted through the vessel upper port to mix the liquid agent with the powder separated by the separator.

25. The apparatus of claim 22 wherein:

a transfer vessel (810), optionally located within the processing chamber, couples the extractor to the vessel in the loading position, the transfer vessel including upper and lower ports sealed by upper (770) and lower (820) valves and including an evacuation port.

26. The apparatus of claim 21 further comprising a sampling device (814) for withdrawing a test sample of powder received from the extractor prior to processing.

27. The apparatus of claim 1 wherein the wire passes through a pressure balancing chamber (504) prior to entry into the reaction chamber.

28. The apparatus of claim 1 comprising an isolator (502) along said wire path and providing said isolation, the isolator comprising:

a first conduit (500, 505) receiving the wire from upstream and having an inner surface of a first minimum cross-sectional area;

a second conduit (506, 512) admitting the wire to the chamber interior downstream and having an inner surface of a second minimum cross-sectional area;

a pressure balancing chamber (504) enclosing respective downstream and upstream ends of the first and second conduits and having a gas inlet port; and

a balancing gas source (514) connected so as to introduce a balancing gas through the gas inlet port and maintain an internal pressure of the balancing chamber slightly below an internal pressure of the reaction chamber downstream of the balancing chamber along the wire path.

29. The apparatus of claim 28 wherein the balancing gas consists essentially of argon, nitrogen, or mixtures thereof.

30. The apparatus of claim 28 further comprising a valve (508; 510) having an open condition in which the wire can pass between the first and second conduits and a closed condition in which the valve blocks the wire path at the gap and seals the second conduit.

31. The apparatus of claim 28 wherein:

the wire has circular cross section with a diameter of 0.40 +/- 0.02 mm at the source;

the first cross-sectional area is 1.5–4.1 mm^2; and

the second cross-sectional area is 7.3–17.0 mm^2.

32. The apparatus of claim 28 wherein:

the wire has a cross-sectional area of 0.1–0.4 mm^2; and

the second cross-sectional area is between 130% and 500% of the first cross-sectional area.

33. The apparatus of claim 28 including at least one pressure sensor (516) for determining a difference between said internal pressure of the balancing chamber and said internal pressure of the reaction chamber.

34. A powder formed by electrically exploding an aluminum-containing wire to form an intermediate powder and then passivating the intermediate powder and wherein the powder comprises in major part nonaggregated particles having a median characteristic particle diameter between 0.05 and 0.5 μm.

35. The powder of claim 34 wherein each particle includes an alumina layer about 1.5nm to about 5nm thick.

36. The powder of claim 34 wherein each particle includes a non-conductive layer about 1.5nm to about 5nm thick.

37. A method for manufacturing an energetic powder comprising:

electrically exploding wire to form an intermediate powder, of which a major portion is nonagglomerated and has characteristic diameters between about 0.05 and 0.5 μm; and

passivating at least an amount of the desired portion of the intermediate powder, to render the passivated powder stable enough to be exposed to air at ambient temperature without spontaneous combustion.

38. The method of claim 37 wherein the wire consists essentially of aluminum.

39. The method of claim 37 wherein the passivation provides the passivated powder with an alumina layer about 1.5nm to about 5nm thick.

40. The method of claim 37 wherein the passivation comprises exposing the powder being passivated to a passivating atmosphere containing argon and oxygen while periodically or continuously mixing such powder to maintain exposure to such atmosphere over a time while maintaining a temperature of such powder at or below 20°C.

41. The method of claim 37 wherein the passivation comprises: coating the powder to be passivated with a coat that retards penetration of oxygen; and exposing the coated powder to an atmosphere, containing an oxygen concentration high enough so that the powder would initially combust absent the coat, for a period of time effective to allow the atmosphere to form a passivating oxide layer on the powder.

42. The method of claim 41 wherein the coat comprises a long chain aliphatic carboxylic acid.

43. The method of claim 42 wherein the coat is removed when the oxide layer has a thickness effective to prevent spontaneous combustion in air.

44. The method of claim 41 wherein the coat comprises a chlorofluorocarbon polymer.

45. The method of claim 37 wherein the passivation is performed while cooling the powder and the time is 10-30 hours.

46. The method of claim 37 wherein the aluminum-containing wire is exploded in a length of between 15cm and 30cm and at a diameter of between 0.30mm and 0.60mm.

47. The method of claim 37 wherein the explosion is performed in an atmosphere consisting essentially of argon or an argon/hydrogen mixture.

48. Powder produced by the method of any of claims 37-47.